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# A PRELIMINARY INVESTIGATION INTO CANE VARIETIES AND INFESTATION BY DIATRAEA SACCHARALIS.

BY

R. W. E. TUCKER, M.A., B.Ed.

The fact of plant varietal resistance to insect attack has been established on broad or general lines for some time past, but only recently has sufficient attention been directed towards establishing and measuring plant resistance towards insect attack according to varieties of cultivated plants in relation to definite pest attacks. Still more recently have the possibilities been considered of breeding plant varieties for resistance to insect attack in a manner comparable with the well established practice of breeding plant varieties immune to disease.

Recent work in various countries has shown that possibilities exist for the utilisation of cane varietal breeding for reduction of insect pest damage, particularly in the case of the small moth borer, *Diatraea saccharalis* (1) (2) & (3). It is most probable, however, that, even though a definite correlation between cane variety and *Diatraea* damage is established, there is much to be done before entomologists are in a position to supply data which is sufficiently definite and useful for incorporation into varietal breeding programmes.

The field data analysed below are therefore considered preliminary investigations only, and do no more at present than indicate the existence of possibilities of effecting a reduction in loss due to *Diatraea*, by means of breeding resistance to borer into cane varieties.

The control of borer attack can be said to rest on three main principles (a) cultural methods, (b) biological control, and (c) reduction of infestation by breeding varieties resistant to moth borer attack.

The first, namely cultural methods, is not an effective control; the common sense precautions of using selected borer-free cuttings as plants and of cleaning up fields after reaping, undoubtedly help, as do all common sense cultural methods, but in the case of moth borer, they do not control the pest.

The second, biological control, has in the case of Barbados, two aspects; control by introduced parasites and control by timed liberations of artificially reared *T. minutum*. The introduced parasite methods, from *Ipobracon* and *Microdus* introduced in 1927, to *Lixophaga* and *Paratheresia*, introduced in 1930, 1934, and 1935, have so far been unsuccessful (6).

The mass liberations of *Trichogramma* have produced results which have been sufficiently apparent and tangible to result in the building up of production from an experimental 23 millions per annum to a minimum of 230 millions per annum, which is now in process of attainment. Nevertheless, though this method has produced an economic reduction in infestation, the drawbacks of its permanency as an annual measure, and its dependence on the full co-operation of the planters is fully recognised, and, therefore, investigations into a possible permanent measure of reduction through the utilisation of borer resistant varieties were started some years ago, and are being carried through and elaborated.

Records of borer damage in random samples of canes from adequate varietal maturity plots have been carried out in 1934, 1935, and 1936. The results of investigations prior to the above have been summarised in (3).

A statistical analysis of the 1935 records is given below, together with details of the experimental lay-out, and method and extent of sampling. From these, the difference in borer damage between varieties, as measured by per cent. joints bored, necessary to enable any one variety to be pronounced significantly more or less bored than any other can be stated.

At the same time, records are given of a considerable series of observations carried out during 1934 on the 1933-35 varietal maturity plots from which can be stated, for the conditions under which this experiment was carried out, (a) the effect of cane variety on total *Diatraea* egg deposition, (b) the effect of variety on the average number of eggs per *Diatraea* egg mass, (c) the effect of variety on the average number of *Diatraea* eggs *per cane shoot*, and (d) a possible idea of varietal resistance to *Diatraea* by determination of percentage dry matter in cane spindles.

Records (a) to (d) are made on six varieties only, as the labour entailed in making a thorough weekly count of *Diatraea* eggs is such that the number of varieties, and of plots of each variety, had to be limited to the amount which experience had shown could be adequately handled by a trained worker. Five plots each of the six varieties B.726, Co.290, B. 2935, B.3124, B.2977 and B.3011 were utilised in the above experiment. In the percentage bored joints counts, however, the full number of twelve randomised plots in each of 18 blocks was used, thus including the varieties B.3127, B.2931, B.3138, B.3125, H. Q. 409 and E. K. 28 in addition to the six named above.

The lay-out of the cane maturity varietal plots of the British West Indies Central Sugar Cane Breeding Station at Codrington conforms with the requirements of modern experimental practice for obtaining data which can be examined statistically, and is as below:—

TABLE I.

<table>
<tr><td>a</td><td>b</td><td>c</td><td>d</td><td rowspan="3">2</td><td rowspan="3">3</td></tr>
<tr><td>e</td><td>f</td><td>g</td><td>h</td></tr>
<tr><td>i</td><td>j</td><td>k</td><td>l</td></tr>
<tr><td colspan="4">6</td><td>5</td><td>4</td></tr>
<tr><td colspan="4">7</td><td>8</td><td>9</td></tr>
<tr><td colspan="4">12</td><td>11</td><td>10</td></tr>
<tr><td colspan="4">13</td><td>14</td><td>15</td></tr>
<tr><td colspan="4">18</td><td>17</td><td>16</td></tr>
</table>

1 to 18 represent blocks of equal size.

a to l represent randomised plots of varieties within the blocks.

The weekly egg counts were made in thirty plots in a total of six blocks as shown below; for convenience in working, the plots were taken in lines from left to right and *vice versa*, along the blocks and the varieties numbered 1 to 5 as they occur in the lines of plots across the blocks.

The arrangement of the six varieties in the randomised maturity plots was as follows: the area shown naturally represents only six out of the 18 blocks of twelve randomised plots, namely 13, 14, 15, 16, 17 and 18 as in Table I.

TABLE II.

| | | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|
| | | | | Co. 290 (5) | | | B 726 (5) | | | | |
| B. 3011 (4) | | B. 3124 (5) | | B. 2977 (5) | | B. 3011 (5) | | | B. 726 (4) | | B. 3124 (5) |
| | | | | B. 2935 (5) | B. 3124 (4) | | | | B. 2935 (4) | B 2977 (4) | |
| | | | B. 2977 (2) | B. 726 (3) | Co. 290 (3) | B. 3011 (2) | B. 2977 (3) | B. 2935 (3) | | | B. 3011 (3) |
| | B. 3011 (1) | B. 3124 (3) | | | | | | B. 2977 (1) | B. 726 (2) | | B. 3124 (2) |
| B. 726 (1) | | Co. 290 (1) | B. 2935 (1) | | B. 3124 (1) | B. 2935 (2) | | | | Co. 290 (2) | |

These 30 plots, each of 16 stools were examined once each week, and each egg cluster found was marked by a spot of paint placed on the cane leaf where it did not interfere with the cluster.

As described in (4), the paint colour and the shape of the mark was different at each examination, so that no count could be confused with the previous one. As an egg cluster was found, the number of eggs it contained was counted, and the result recorded, together with observations as to parasitism and destruction by predators.

A trained worker was employed continuously on this experiment, and his work was checked over from time to time in the field; his written field records were also checked at intervals in their various plots, by means of the coloured spot index for each date.

These records were entered and filed week by week, and form the basis of the analysis given below. A record of one such weekly entry is given in order to demonstrate the method, and to illustrate the apparent differential egg deposition according to variety. To print each weekly record is obviously impossible. The record given is a fair average sample.

From these weekly records, extending over a period of 36 weeks, the data for Tables given later are extracted. A bracket around an egg count indicates that the egg mass was parasitised when counted; inverted commas indicate that the egg mass had been destroyed by predators.

TABLE III.

RECORD OF FIELD DATA FROM FIVE PLOTS EACH OF SIX CANE VARIETIES.
16 STOOLS TO A PLOT.
August 9, 1934.

| Variety | Plot | Clusters | | Eggs | Total Eggs | Parasitism |
|---|---|---|---|---|---|---|
| B.726 | 1 | 4 | | "7" (13) 5 (12) | | 13, 12 |
| | 2 | 1 | | (10) | | 10 |
| | 3 | 4 | 14 | 17, 21, 15, 18 | 220 | |
| | 4 | 3 | | (19) (26) (17) | | 19, 26, 17 |
| | 5 | 2 | | (16) 24 | | 16 |
| Co.290 | 1 | 8 | | (24) (13) (15) (13) (11) (16) 13, 30. | | 24, 13, 15, 13, 11, 16 |
| | 2 | 6 | 38 | (17) (18) (32) (4) 36, 10 | | 17, 18, 32, 4 |
| | 3 | 6 | | (39) (20) (16) (5) 19 "3" | 638 | 39, 20, 16, 5 |
| | 4 | 17 | | (13) (12) (20) (31) (14) (20) (26) (2) 36 7 "17" 7 "10" 9 19 10 "10" | | 13, 12, 20, 31, 14, 20, 26, 21 6 |
| | 5 | 1 | | 21 | | |
| B.2935 | 1 | 1 | | 16 | | |
| | 2 | 0 | | | | |
| | 3 | 0 | 2 | | 33 | |
| | 4 | 0 | | | | |
| | 5 | 1 | | (17) | | 17 |
| B.3124 | 1 | 0 | | | | |
| | 2 | 2 | | (14) "6" | | |
| | 3 | 0 | 7 | | | 14 |
| | 4 | 2 | | (16) 21 | 105 | |
| | 5 | 3 | | 16, 24, 8 | | 16 |
| B.2977 | 1 | 3 | | (9) (21) (9) | | 9, 21, 9 |
| | 2 | 0 | | | | |
| | 3 | 4 | 8 | (5) (13) (15) (19) | 107 | 5, 13, 15, 19 |
| | 4 | 1 | | (16) | | 16 |
| | 5 | 0 | | | | |
| B.3011 | 1 | 1 | | (16) | | 16 |
| | 2 | 2 | | (9) (26) | | 9, 26 |
| | 3 | 3 | 8 | (21) (16) "18" | 135 | 21, 16 |
| | 4 | 0 | | | | |
| | 5 | 2 | | (13) 16 | | 13 |

The foregoing is an outline of the data relating to moth borer and cane variety, obtained on an adequate experimental basis in 1934 and 1935. These data fall into two divisions, namely, the determination of cane varietal effect on moth borer as shown by egg deposition in a series of equal randomised plots during the growing season of 1934, and the measurement of final borer damage to the canes when reaped in 1935.

The latter set of data will be dealt with first, to establish the fact of significant differences in final borer damage according to variety. The 1934 data on egg deposition (a) per plot, (b) per average egg mass, and (c) per cane shoot, according to variety, responsible for the 1935 infestation, can then be compared with final borer damage for each variety, and also with a determination of percentage dry matter in cane spindles for the six varieties in which egg collections were made.

The lay-out of the varietal maturity experiment has been given, namely eighteen blocks of twelve randomised plots : the randomisation of varieties in the twelve plots of each block is, naturally, different in each block. The twelve varieties thus randomised were :—B.3124, B.3127, B.726, B.2935, B.3011, B.2931, B.3138, B.3125, B.2977, Co.290, H.Q.409 and E.K.28.

Each plot contained sixteen stools planted in cane holes four by four at the rate of 1930 stools to the acre. The size of each plot is, therefore, approximately 0.0083 acre.

The eighteen blocks were reaped six at a time at three different periods of the reaping season of 1935, namely February 7th, March 29th and April 26th. This, however, is no drawback from the entomological point of view, as the total of the three reapings then corresponds more closely to an average sample of a crop which normally takes over three months to reap, than would borer counts made at a single reaping.

* The statistical analysis of the bored joint counts made in eighteen plots each of twelve varieties will be taken as determining the significant difference between the percentages of bored joints given by the average of all three reapings of each variety. The results of a statistical analysis of the figures for each reaping will also be given for purposes of comparison of the general order of infestation for each variety in the three reapings, with the final order for the averaged total reapings.

The method of sampling when obtaining the data analysed was as follows:—

Each plot has been stated to comprise sixteen cane stools, and it is a fair estimate to consider that this represents 150 reapable canes per plot, with the exception of thin canes such as Co.290 which would contain more than 150 reapable canes per plot. At each reaping, 15 canes were supplied at random from each plot, thus ensuring that the sample was representative as far as all stages of cane formation is concerned. These canes were examined by trained

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* The writer wishes to acknowledge his indebtedness to N. H. Carrier, B.A., of Clare College, Cambridge, and N. Mehta, Ph.D., at that time at Rothamstead, for making these statistical analyses.

and supervised workers, who counted bored joints on external evidence, the canes being stripped of all trash to the very top, for this purpose.

Thus, at each reaping, approximately ten per cent. of the reapable canes in each plot were examined, or fifteen canes from each plot of 0.0083 acre; with a ten per cent. sample, no question arises of inadequacy of the basis of the figures given below.

In the following Table, the twelve varieties are listed in the order of magnitude of infestation. The percentage joint infestation is the average of three reapings of each variety.

**TABLE IV.**

| Variety | Percentage Joints Infested | No. of Infested joints per plot. |
|---|---|---|
| Co.290 .. .. | 11.33 | 692 |
| B.3127 .. .. | 13.25 | 1,174 |
| B.726 .. .. | 14.24 | 1,244 |
| B.2931 .. .. | 14.93 | 1,073 |
| B.2935 .. .. | 16.13 | 1,390 |
| B.3125 .. .. | 18.03 | 1,476 |
| B.3011 .. .. | 18.59 | 1,358 |
| B.3138 .. .. | 19.74 | 1,540 |
| H.Q.409 .. .. | 21.35 | 1,819 |
| B.2977 .. .. | 21.66 | 1,582 |
| B.3124 .. .. | 22.10 | 2,160 |
| E.K.28 .. .. | 22.39 | 1,696 |

Any difference of 4.088 between percentage joint infestation is highly significant.

Thus B.2935 *et seq.* are significantly more infested than Co.290, and B.2931 is nearly in this category.

Taking B.726 as a standard in Barbados for this group of varieties, B.3011 *et seq.* are significantly more infested, with B.3125 very nearly so. It is also possible to say that B.3124, E.K.28 and H.Q.409 are significantly more infested than the new variety B.2935, which can be taken now as the standard cane for the black soil or dryer areas of Barbados.

For comparison with the foregoing, the order of magnitude of infestation in varieties is given below for each of the three reapings. There is, it will be seen, a reasonable maintenance of the general order of varietal infestation.

TABLE V.

| First Reaping February 7th., 1935. | | Second Reaping March 29th., 1935. | | Third Reaping April 26th., 1935. | |
|---|---|---|---|---|---|
| Variety | Percentage Joints Infested | Variety | Percentage Joints Infested | Variety | Percentage Joints Infested |
| Co.290 .. .. | 10.01 | B.2931 | 12.31 | Co.290 | 10.45 |
| B.3127 .. .. | 11.76 | Co.290 | 13.54 | B.3127 | 13.67 |
| B.726 .. .. | 14.01 | B.3127 | 14.32 | B.726 | 13.77 |
| B.2935 .. .. | 15.22 | B.726 | 14.93 | B.2935 | 14.74 |
| B.3011 .. .. | 16.23 | B.3125 | 15.18 | B.2931 | 16.25 |
| B.2931 .. .. | 16.23 | B.2935 | 18.44 | B.3125 | 17.03 |
| B.3138 .. .. | 18.18 | B.3138 | 20.16 | B.3011 | 18.86 |
| B.3125 .. .. | 18.89 | B.3011 | 20.67 | E.K.28 | 19.32 |
| H.Q.409 .. .. | 19.30 | H.Q.409 | 21.06 | B.3124 | 20.02 |
| B.2977 .. .. | 22.41 | B.2977 | 21.60 | B.3138 | 20.89 |
| B.3124 .. .. | 24.67 | B.3124 | 21.60 | B.2977 | 20.96 |
| E.K.28 .. .. | 24.97 | E.K.28 | 22.87 | H.Q.409 | 23.68 |

In the first reaping, any difference of 5.695 or more between percentage joint infestations is highly significant.

Taking B.726 as a standard Barbados variety, we find that only B.2977, B.3124 and E.K.28 are significantly more infested, though H.Q.409 is very nearly so, and no varieties are significantly less infested.

In the second reaping, any difference of 6.620 or more between percentage joint infestation is highly significant.

Taking B.726 as a standard, again only B.2977, B.3124 and E.K.28 are significantly more infested, and no varieties are significantly less infested.

In the third reaping, any difference of 7.015 or more is significant; thus B.3138, B.2977 and H.Q.409 are significantly more infested than B.726, with B.3124 very nearly in this category.

It is obvious that Table IV, which deals with the values obtained from all reapings, gives a more adequate picture of the order of magnitude of infestation in varieties and is more accurate. Table V and the analyses of each reaping are given for purposes of comparison only.

The fact that significant differences in borer attack emerge from the examination of plots of the size described in the experimental lay-out utilised to obtain entomological data, may possibly be enhanced by the following considerations.

An experiment was carried out in Barbados in 1935 in which twelve plots each of 1/40 acre of B.726 were treated as follows. In every plot, egg masses were counted and recorded three times weekly; in every alternate plot, the egg masses instead of being marked as in routine egg counts, were removed and destroyed. Thus six plots were left normal and six alternating plots were 'sterilised' by having all egg masses removed before hatching could take place. At the end of each month, one normal and one adjacent sterilised plot were reaped and larval damage and live larvae carefully counted and recorded. It was found there was surprisingly little difference between infestations at the end of each month in each 1/40 acre plot. This shows a considerable migration or dispersal of larvae from the normal plots into the sterilised plots;* for every 10 larvae hatching in a given plot, 3 *effective larvae at least* would migrate to adjoining plots. These records and the varietal plot egg records given below were submitted to Mr. N. Carrier for a statistical examination at the Agricultural Statistical Laboratory, Cambridge, and in connection with the above analyses of varietal infestation by borer, he stated that "Figures submitted showing "the extent of migration or dispersal of *D. saccharalis* larvae in contiguous "plots of 1/40 acre show a definite high fluidity of these larvae. Other figures "giving continuous egg deposition in each of five plots of six out of the twelve "varieties dealt with above, show that the variety Co.290 causes a higher weekly egg density in each Co.290 plot, from which the larval fluidity will cause "a spread of larvae through surrounding plots. Owing to the small number "of replications at each reaping,† this effect will not be controlled, but will "reduce the efficiency considerably."

* This migration or dispersal of larvae, referred to below as larval fluidity, has since been confirmed by two further experiments carried out in 1936.

† From the point of view of an entomological experiment such as the above, and not from any other point of view.

When, however, the combined records of all three reapings are analysed, a greater statistical efficiency is obtained, though, even so, the efficiency of an entomological experiment as above is not nearly as high as that required for a purely agricultural experiment. The causes for this are, the larval fluidity just mentioned, and the undoubted erratic behaviour of the moth *D. saccharalis* which in turn leads to fluctuations in the noticeable effects of its parasites and predators. The combined effect being to produce statistically uncontrollable (for the lay-out described above) fluctuations in infestation.

In spite of the foregoing, Table IV gives a reasonable measure of a difference in percentage joint infestation between varieties, which can be considered as due to some inherent varietal qualities and not merely due to chance.

The results obtained from the maturity varietal plots reaped at Codrington Experiment Station in 1935 can be compared with the results obtained from the maturity varietal plots reaped there in 1934 and 1936. The analyses of the records for these two years are of interest mainly in showing that with twelve varieties in 1934 ranging from 9.50 per cent. internode infestation to 27.02 per cent. (varieties B.3063, Co.281, B.3011, B.2935, Ba.11569, B.891, B.726, SW.111, P.O.J.2878, B.417, Q.813, ME.17) a difference between infestations of 4.87 is highly significant.

In the 1936 reapings, only six varieties were planted for this experiment, (B.2935, B.726, B.3239, B.3234, B.3216), and infestation ranged from 12.28 per cent. to 17.75 per cent. internode infestation. Using the same standard of significance as in all of the foregoing analyses, namely 1 per cent., a difference of 4.54 between infestations is highly significant. The results of the three years, indicate that a difference in internode per cent. infestation of between 4.5 and 5.0 is highly significant in the case of varietal plot experiments.

The 1935 maturity varietal plot reapings only are considered in detail in this paper, as weekly egg counts during the main growth period in 1934 were made in the 1933—35 varietal plots only, and without such egg counts as detailed in this paper, conclusions as to varietal resistance, etc., appear likely at this stage of investigaion to be incomplete.

These preliminary investigations, therefore, show that varietal resistance to borer exists, and can be measured even between a group of local varieties such as Barbados seedlings, (which show less marked divergence in infestation than do most imported varieties), and open up the possibility of use being made of this fact.

With varietal resistance must be correlated field data ~~of~~ on differential *Diatraea* egg deposition according to variety, and the final results on stalk infestation, and on cane rendered unreapable by *Diatraea* attacks.

The following records indicate the nature of this relation.

In the first place, final borer infestation would appear to be related to the growth habit as shown by density of growth of the cane variety, and an indication of the density of cane growth according to variety can be obtained from the following Table, compiled from the Botanist's records of the average number of shoots per stool for each variety in each month.

## TABLE VI.

AVERAGE CANE SHOOTS PER STOOL PER MONTH.

| Month. | Variety. | | | | | |
|---|---|---|---|---|---|---|
| 1934. | B.3124 | B.2977 | B.3011 | B.2935 | B.726 | Co.290 |
| March .... | 6.4 | 5.2 | 14.0 | 11.3 | 12.8 | 23.0 |
| April .... | 10.0 | 8.6 | 15.0 | 15.8 | 16.5 | 28.8 |
| May .... | 11.1 | 11.6 | 15.0 | 17.6 | 17.9 | 34.4 |
| June .... | 10.7 | 11.2 | 13.0 | 17.7 | 17.0 | 32.0 |
| July .... | 10.1 | 11.5 | 12.0 | 16.8 | 16.2 | 30.1 |
| August .... | 9.8 | 11.0 | 11.0 | 15.0 | 16.0 | 28.2 |
| September. | 9.7 | 10.2 | 10.0 | 14.1 | 15.5 | 26.0 |
| October .... | 10.7 | 10.0 | 10.0 | 13.9 | 15.6 | 24.6 |
| Average shoots per stool over a period of eight months .... | 9.81 | 9.91 | 12.50 | 15.27 | 15.94 | 28.39 |

Reading from left to right in the above Table for each month enables a definite comparison to be made between the density of growth for each variety in that month, as the figures given for each month are the average number of shoots per cane stool for each variety, taken from a considerable series of counts made by the Botanist and his staff.

The average given under each column provides an index of the amount of cane or cane shoots per stool of each variety available for *Diatraea* egg deposition over a total period of eight months, including the months which the writer considers to be the critical ones in which the major economic borer damage is inflicted each year.

It will be noticed that the six varieties are placed in subsequent Tables, in the order of magnitude of final infestation established in Table IV, namely, low to high Co.290, B.726, B.2935, B.3011, B.2977, B.3124.

This order of magnitude of infestation is, however, almost identically the reverse of the order of magnitude of the total monthly averages of cane shoots as given in the above Table VI; that is, the variety with the greatest total shoots, indicating greatest density of growth, has the lowest final infestation, and the variety with the lowest density of shoot production has the highest infestation.

This point must also be considered in relation to other Tables given below.

At this preliminary stage of investigation, no definite statements can be based on the above, but the facts are placed on record, and some deductions made.

The next most interesting point, however, is that, as Table VII will show, the varieties of average densest growth are usually the ones most favoured by *Diatraea* for heavy egg deposition. Co.290 is outstanding both as to density of growth and density of egg deposition: B.726 maintains its position as second, but thereafter the general order changes, B.2935 for example, becoming fifth in order—instead of third.

**TABLE VII**

*Number of Egg Clusters in 80 stools per Month.*

| Month 1934. | Variety | | | | | |
|---|---|---|---|---|---|---|
| | Co.290 | B.726 | B.2935 | B.3011 | B.2977 | B.3124 |
| March .. | 26 | 34 | 32 | 20 | 12 | 18 |
| April .. | 78 | 21 | 20 | 14 | 14 | 37 |
| May .. | 140 | 77 | 76 | 102 | 59 | 78 |
| June .. | 169 | 66 | 48 | 68 | 43 | 58 |
| July .. | 259 | 72 | 44 | 78 | 61 | 72 |
| August .. | 104 | 63 | 28 | 44 | 35 | 42 |
| September | 98 | 48 | 51 | 44 | 39 | 28 |
| October .. | 256 | 76 | 42 | 57 | 40 | 59 |
| Total Clusters | 1130 | 457 | 341 | 427 | 303 | 392 |
| Mean of Clusters for 8 months. | 141.2 | 57.1 | 42.6 | 53.4 | 38.0 | 49.0 |
| Average Eggs per Cluster over a period of 8 months. | 18.8 | 16.5 | 17.5 | 17.1 | 18.3 | 17.8 |

A difference between variety means of clusters for 8 months of more than 4.6 ~~2.84~~ is significant (in this and all foregoing and subsequent statistical analyses a one per cent. standard of significance is adopted). Though this shows that, on the above monthly averages of egg clusters per variety, Co.290 is nearly significantly different from the Barbados varieties, it is considered that a difference which is biologically significant exists between some of the Barbados varieties tabulated. It has been suggested before (3) that there may be a varietal chemo-tropism which also operates in addition to density of growth, in determining a preference of varieties by *Diatraea* for egg deposition.

There are reasons based on general insect behaviour for thinking that this is a possibility, but no direct evidence has, to the writer's knowledge, been obtained on this point for cane varieties. Assuming, however, that it does exist, it would furnish an adequate reason for the fact that density of egg deposition is not fully correlated with varietal density of cane growth in Table VI.

It will be noticed that, in Table VII last line, the average eggs per cluster are given over a period of 8 months for comparison with other data given in Table VII. As it may be of interest to show how these figures were obtained, the records of average *Diatraea* eggs per cluster per month for each variety are given below.

## TABLE VIII.

*Average Diatraea Eggs per Cluster for Each Variety.*

| Month 1934 | Variety | | | | | |
|---|---|---|---|---|---|---|
| | Co.290 | B.726 | B.2935 | B.3011 | B.2977 | B.3124 |
| March | 21.5 | 16.2 | 15.7 | 15.1 | 16.7 | 22.5 |
| April .. | 17.3 | 16.5 | 14.7 | 17.5 | 17.5 | 19.0 |
| May .. | 18.2 | 15.2 | 15.8 | 17.3 | 19.4 | 17.8 |
| June .. | 20.3 | 16.8 | 16.7 | 17.9 | 24.1 | 13.5 |
| July .. | 20.4 | 18.5 | 18.4 | 18.5 | 19.4 | 20.0 |
| August | 18.4 | 16.3 | 16.9 | 17.8 | 16.3 | 17.8 |
| September | 17.0 | 16.6 | 19.3 | 15.7 | 17.0 | 18.2 |
| October | 17.2 | 15.9 | 22.2 | 17.0 | 15.7 | 14.0 |
| Average Eggs per Cluster | 18.8 | 16.5 | 17.5 | 17.1 | 18.3 | 17.8 |

A difference between variety means of eggs per cluster of more than 2.94 is significant. The above Table shows no significance between average eggs per cluster. Again, however, it is possible that the difference shown between the columns for B.726 and Co.290 for example, resulting in an average of 2.5 eggs per cluster for each cluster laid in Co.290 over a period of 8 months has a biological significance when one considers the tremendous number of egg clusters which are laid in any fields of these varieties.

In spite, therefore, of the lack of significance in the analysis of the above Table of eggs per cluster, it would appear that Co.290, which has the lowest final joint or internode damage by *Diatraea*, has nevertheless the greatest number of eggs deposited per stool, (and therefore per plot or per acre), and has the highest average of *Diatraea* eggs per cluster laid. B.2977, however, which has a very high final total damage by *Diatraea*, has the lowest total egg deposition over a period of eight months, which indicates that *Diatraea* larvae have a higher rate of survival in this variety, due perhaps to its being more easily penetrated by the larvae: that is, it is a variety susceptible to borer attack.

There remains a final analysis to be made from the foregoing set of figures, and that is the average number of *Diatraea* eggs deposited *per shoot* of each variety in each month.

This is given in Table IX below, and, reading from left to right, it is possible to compare, month by month, the average number of eggs deposited *per cane shoot* for each variety in each month.

The final totals, however, of eggs laid per shoot of each variety over a period of eight months provides figures which are more readily comparable with the final order of total damage (Table IV) for each variety.

## TABLE IX.

*Average Diatraea Eggs per Cane Shoot per Month.*

| Month 1934 | Variety. | | | | | |
|---|---|---|---|---|---|---|
| | Co.290 | B.726 | B.2935 | B.3124 | B.2977 | B.3011 |
| March .. | 0.29 | 0.54 | 0.55 | 0.27 | 0.48 | 0.79 |
| April .. .. | 0.61 | 0.26 | 0.15 | 0.20 | 0.35 | 0.75 |
| May .. .. | 0.92 | 0.81 | 0.85 | 1.47 | 1.23 | 1.56 |
| June .. .. | 1.34 | 0.82 | 0.51 | 1.17 | 1.16 | 0.91 |
| July .. .. | 2.20 | 1.02 | 0.60 | 1.50 | 1.29 | 2.15 |
| August .. | 0.84 | 0.80 | 0.39 | 0.89 | 0.65 | 0.95 |
| September .. | 0.80 | 0.64 | 0.86 | 0.86 | 0.81 | 0.65 |
| October .. | 2.16 | 0.96 | 0.82 | 1.20 | 0.78 | 0.96 |
| Total eggs per shoot for period of 8 months. | 9.16 | 5.85 | 4.74 | 7.56 | 6.75 | 8.72 |
| Mean of Eggs per Shoot. | 1.14 | 0.73 | 0.59 | 0.94 | 0.84 | 1.09 |

A difference between variety means of 0.41 is significant. Thus Co.290 and B.3011 have a significantly greater number of eggs deposited per shoot per month than B.2935 has, and B.3124 comes nearly into this category. Considering that a one per cent. standard of significance has been adopted throughout these calculations, the above results indicate that the average *Diatraea* eggs per cane shoot per month provides a good basis for investigation of varietal susceptibility of resistance to borer attack.

Thus, although Co.290 has the greatest number of eggs deposited per shoot in a given period, yet, instead of suffering the greatest joint or internode damage at reaping time, it suffers the least; on the other hand, B.3124 which comes very close to Co.290 in the number of eggs per shoot over a given period, suffers nearly double the final amount of damage due to *Diatraea*. As these figures are of eggs per shoot and therefore independent of the number of shoots per variety, it would appear that Co.290 is resistant to attack, that B.3124 is susceptible to borer attack, though not so susceptible as B.2977 which has approximately the same figure for damage (Table IV), though it has fewer eggs per shoot. Thus B.2977 emerges as the most susceptible variety and B.3124 as the next most susceptible out of the varieties under consideration.

T. E. Holloway (2) states "it has become evident that there are *two sorts "of resistance* to the borer—resistance to the moth and resistance to the larvae": also "it was found that stalk hardness has something to do with final infestation "—the harder varieties resisting the borer to some extent—but that there are "evidently other factors still unknown." It is presumed that in the above quotation 'resistance to the moth' corresponds to greater or lesser chemotropism mentioned in the foregoing: or to oviposition stimulus or deterrence on the part of the cane leaf surface (3).

L. D. Cleare (1) also considers that resistance is "due in all probability to "the fibrous content and its arrangement in the cane."

In the present preliminary studies to find out whether any entomological data can be obtained which will have any genetical value, use has been made of Hazelhoff's method of determining the dry matter content of the central cane leaf spike, and this factor has been used as an index of borer resistance or susceptibility (Hazelhoff, however, used it against white top borer in Java, for which insect the correlation is likely to be more direct than with the cane stem borer under discussion).

Thus, in 1934, twenty cane leaf spikes were taken for each of the six varieties in which the foregoing tabulated field data were being obtained, and analyses of per cent. dry matter were made.

Once again, it must be pointed out that this was an experiment to gain information only, and its inadequacy is fully recognised in that no uniformity trials were made to determine whether twenty spikes was an adequate sample, nor were the samples taken from shoots all of exactly the same growth age as doubtless they should have been.

The procedure of the experiment was as follows. One hundred and twenty clean dry tins were labelled and weighed, and the weights recorded. The tins were then taken into the field, and in case of tins 1—20, a spike, taken at random from a shoot of Co.290 was coiled or folded up and the lids replaced; in tins 21—40, spikes of B.2935 were placed, and so on. These 120 tins were then returned at once to the Laboratory, and the analysis for percentage dry matter for each shoot was undertaken by the staff of the Analytical Laboratory.

The results, summarised, are as follows, varieties being placed in the order of magnitude of mean percentage dry matter. At the same time the infestation figures taken from Table IV are placed alongside for comparison.

TABLE X.

| Variety | Mean Percentage Dry Matter | Mean Percentage Joint Infestation |
|---|---|---|
| B.2977 .. .. | 21.43 | 21.66 |
| Co.290 .. .. | 21.19 | 11.33 |
| B.2935 .. .. | 20.09 | 16.13 |
| B.3011 .. .. | 18.38 | 18.59 |
| B.726 .. .. | 16.88 | 14.24 |
| B.3124 .. .. | 15.25 | 22.10 |

Out of the above six varieties, four agree with the idea that the higher the mean percentage of dry matter, the lower the final infestation by borer, and two do not. The exceptions, namely B.2977 and B.726, are rather outstanding, particularly B.2977. These varieties are so much out of place that either the records are at fault or the "other factors still unknown", which Holloway remarks on, are of considerable effect.

As stated, these investigations are of a preliminary nature, in that it is recognised that none of the experiments is on a sufficiently adequate scale, because of the limitation of staff and of time to furnish data which can be considered as final. The objective has been to ascertain the degree of varietal difference in susceptibility to borer attack, and to trace, whenever possible, the factors underlying, or contributing to, these varietal differences, in order that the possibility of their use in cane breeding work can be considered.

The fact of difference in varietal susceptibility to attack by *Diatraea saccharalis* has been established in Barbados and in other cane growing countries, for the standard varieties of cane grown in and suitable to these areas. In Barbados, the significant difference in percentage joint infestation necessary to distinguish any one variety as more or less susceptible than another has been established for the cane growth conditions prevailing for cane reaped in 1934, 1935, and 1936 in varietal maturity plots at Codrington.

Various phenomena of *Diatraea* behaviour during a period of eight months of cane growth have also been recorded for 1934, such as the effect of variety on total egg deposition: effect of variety on average number of eggs deposited per egg mass: and the effect of variety on the average number of *Diatraea* eggs per cane shoot. This is the only year in which such records are available to correlate with varietal infestation at the reapings of such plots.

There remains to compare the figures obtained for joint or internode infestation in plot experiments with those found for the same varieties under plantation growth, and also to record the average number of joints per cane for the standard varieties under consideration for correlation with average number of stalks per stool. The latter point is important inasmuch as a given percentage infestation of a cane with few joints per stalk cannot truly be compared with a corresponding percentage infestation in a cane which has a large number of joints per stalk. Neither can the average number of stalks per stool for each variety be left out of consideration: otherwise the estimation made of reduction or increase in infestation, in damage, or in general *Diatraea* population due to varietal effects may be misleading if joint or internode percentage only is considered.

It must also be pointed out that, as the search for new and better cane varieties is progressive, and not static, the varieties which are planted each year in the varietal plots differ each year, many being discarded each year, and many new ones brought in each year. This is made clear on page 130. The only varieties which remain common to experimental plots and plantation fields are the present standard Barbados varieties B.726 and B.H.10(12), and the recently established new variety, B.2935. As B.H.10(12) does not figure in the dry or coastal area plantations, nor in the varietal plots arranged to test new varieties for the dry areas, B.H.10(12) does not appear in any of the foregoing discussions, which are based solely on the dry area plots at Codrington Experiment Station, near Bridgetown.

It is therefore possible to compare experiment plot figures and plantation figures, and to give average joints per cane for two varieties only, namely the well established B.726 and the newly established variety B.2935 thus:

TABLE XI.

| Variety | Joint Infestation in Plots | Joint Infestation on Plantations | Average Joints per cane | Average Shoots per Stool | Final Shoots Reapable per Stool | Final Shoots Unreapable per Stool. |
|---|---|---|---|---|---|---|
| B.726 .. | 14.24% | 15.97% | 29.5 | 15.94 | 11.00 | 0.92 |
| B.2935 .. | 16.13% | 17.76% | 26.4 | 15.27 | 8.55 | 1.15 |

The above figures all apply to the crop planted in 1933, grown in 1934 and reaped in 1935. It happens that 1934 was a year of abnormally low rainfall, particularly during the critical period of cane growth and *Trichogramma* liberations. This is known to have affected the percentage of joint infestation (5) but records of joints per cane back to 1932, in the case of B.726, show that this factor remains reasonably constant, despite annual climatic fluctuations. Thus, for B.726, the average joint counts are:—

| 1932 | 1933 | 1934 | 1935 |
|---|---|---|---|
| 29.1 | 29.3 | 29.9 | 29.5 |

One might expect that the number of joints per cane would be a constant varietal character; unfortunately, however, though the number of joints per cane may remain reasonably constant within the variety, the size of the joints would be affected by climate, which, in turn, would affect the apparent prevalence of borer in that (purely as a comparison) three small joints may be damaged one year by a single borer instead of two larger joints in a better year.

From Table XI it will be seen that both varieties produce very nearly the same number of *shoots* per month: the average per stool over a period of eight months being 15.94 shoots for B.726, and 15.27 shoots for B.2935. Field counts of reapable *canes* per stool in 1935 show that B.726 produced an average of 11.00 reapable canes per stool, and B.2935 produced an average of 8.55 reapable canes. This disparity may be in part due to the fact that, as shown by bored joint counts in reaped canes, B.2935 appears to be more susceptible to borer than B.726, the difference being, in the writer's opinion, biologically significant though not yet proved mathematically significant. Possibly because of this, and because B.2935, judging from present evidence, breaks down more readily under borer attack than does B.726, the final result is that B.2935 eventually has over 22 per cent. fewer canes per stool when reaped than B.726 has.

Further, although the percentage joint infestation is higher in the case of B.2935, the actual number of bored joints *per cane* is practically the same in each case, namely, 4.71 joints bored *per cane* for B.726 and 4.69 joints bored *per cane* for B.2935.

The difference in varietal infestation between B.726 and B.2935 depends, therefore, not alone upon the percentage of joints infested, but upon the number of reapable canes per stool, the number of joints per cane, and the number of canes rendered unreapable because they have been destroyed by borer attack.

It has been stated that B.726 has, on an average, (from 2,833 stools counted) 11.0 reapable canes per stool, and that B.2935 has (from 1,068 stools counted) 8.55 reapable canes per stool. The same counts, however, show that B.726 had 0.92 unreapable canes per stool, and B.2935 had 1.15 unreapable canes per stool (i.e. 25 per cent. more unreapable canes per stool) which bears out the above deduction that B.2935 is biologically more favourable to borer than B.726.

This conclusion, taken in conjunction with the fact that plantings of Ba.11569, which in recent years have given the lowest joint infestation at factories, have diminished to the extent that no joint infestation counts of Ba.11569 were made at factories in 1936, has been a contributing cause to a slight rise in infestation in 1936 compared with 1935. Such evidence as is available at present points to varietal changes causing an increase rather than a decrease in infestation in the past few years, because B.2935, though not classified at present as a cane susceptible to borer, is undoubtedly more infested in plantation fields than the Ba.11569 which it has almost entirely replaced of recent years in the drier black soil areas.

There is a possibility that, as plantings of Ba.11569 diminished from being almost universal in the black soil areas to occasional fields, the infestation of such fields would be lower than former mass plantings of that variety. This,

however, is offset by the fact that counts of Ba.11569 became progressively fewer to vanishing point, and the first replacement of Ba.11569, namely B.891, was definitely seriously susceptible to borer attack, and by the fact that the subsequent extended plantings of B.2935 are more heavily bored than the reduced plantings of Ba.11569, and cannot therefore be said to have reduced borer infestation counts at all. There is, in fact, some justification as shown above, for considering that the reverse has taken place, and that varietal changes of proportional plantings within the last 3 years have increased infestation.

In the foregoing preliminary investigations it has been possible to compare only two standard varieties, namely B.726 and B.2935, both of which varieties do not, according to present data submitted to mathematical analysis, differ significantly in their internode infestation. If it were possible to compare, in the above manner, a range of varieties, including two or more that were mathematically significantly different in internode infestation, facts capable of future application might emerge. The amount of data obtained would, however, in that case, be much greater than that reviewed in this paper.

At present, therefore, it is indicated that

(a) The number of shoots per stool, which is a varietal characteristic, influences *Diatraea* egg deposition and therefore the number of *Diatraea* which survive all hazards to become effective borers.

(b) That there is a definite and measurable young larval migration to adjacent plots or stools of cane, quite apart from long distance migration on air currents.

(c) That cane variety influences the number of eggs deposited per cane shoot and per egg cluster and so, with (a) influences *Diatraea* population in any one variety.

(d) That varietal characteristics, such as stalk hardness, fibre content, or the factor which is indicated by percentage dry matter of shoot spindles, influence the power of larvae to penetrate into and permanently damage cane shoots and stalks.

(e) That the number of reapable canes produced per stool is a varietal characteristic, distinct from the number of shoots* produced; but is complicated by differential death rate of shoots and canes due to borer, and that the number of joints per cane is also a varietal characteristic which influences percentage internode counts.

(f) Both the number of joints or internodes per cane, together with reapable and unreapable canes per stool must be considered in conjunction with percentage joint or internode infestation before it can be said that any given variety is susceptible or not susceptible, or that it increases or decreases *Diatraea* population to an extent which makes consideration by cane breeders worth while.

* The differential death rate of shoots, as measured by dead heart counts, has been investigated on an adequate scale in 1936, but unfortunately, with the exception of B.726 and B.2935, all the varieties are different from those which form the subject of this paper. Present data points, however, to the fact that differential death rate of shoots, according to variety, does exist; if it is possible to link this up each year with average eggs per shoot, as in Table IX, definite progress will have been made.

Until further and more elaborate work on these lines has produced definite facts which can connect the early stages of varietal growth with final borer infestation, it does not appear as yet that percentage joint infestation taken by itself is sufficient to determine whether any cane variety will definitely assist or hamper the control of *D. saccharalis*.

Nevertheless, the foregoing preliminary investigations indicate that the requisite relevant facts can be obtained, and may eventually be utilised to breed canes which will limit the damage caused by *D. saccharalis* without sacrificing any qualities at present held to be desirable from the point of view of tonnage and of sugar production per acre.

## Summary


1. An account is given of preliminary field experiments carried out in 1934 on the 1933—35 varietal maturity plots at the British West Indies Central Sugar Cane Breeding Station at Codrington, Barbados. The lay-out and scope of the experiments is described.

2. From weekly egg counts over a period of eight months in six varieties of cane, results are tabulated showing the effect of cane variety on (a) total *Diatraea* egg deposition (b) average number of eggs per *Diatraea* egg mass, and (c) average number of *Diatraea* eggs per cane shoot. A table is also given showing difference in number of shoots produced per stool according to variety month by month.

3. From a statistical analysis of the percentage joint infestation of cane varieties in 18 blocks each of 12 randomised plots, it is shown that significant differences in borer infestation, due to variety, do exist, but that there appears to be less difference between successful commercial local varieties than between imported foreign varieties or local varieties rejected after trials. Attention is drawn to the fact that a definite and measurable larval migration exists between contiguous experimental plots, quite apart from early larval migrations on air currents. This larval migration must be taken into consideration in any assessment of control over *Diatraea* by means of experimental plots, blocks or fields.

4. Differences in varietal internode infestation counts are correlated with the information given under 2, and with preliminary experiments giving the percentage dry matter in the central cane spikes. Attention is drawn to the fact that the number of joints per cane, and the number of reapable and unreapable canes per stool (also apparently varietal characteristics) must also be considered in conjunction with joint or internode infestation counts.

5. The results of this preliminary work show that it may be possible by more extended investigations to determine the factors which produce the now recognised varietal differences in *Diatraea* infestation, and so open up the possibilities of cane breeding stations incorporating resistance to *Diatraea*

infestation into breeding programmes. Indications as to the factors concerned are given, and data set out which show that varietal changes and proportional plantings thereof are likely to have caused a slight rise in average infestation during the past two or more years in Barbados.

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